Using Social Annotations to Augment the Learning Space and Learner Experience

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ABSTRACT
Learning has always been considered a social and collaborative activity. From the social constructivism perspective, students learn through the process of sharing experiences and build knowledge and understanding through discussion. This pilot study demonstrates the successful integration of an online social annotation tool in a Python programming workshop that allows students to discuss learning material and code segments with their fellow classmates. We investigate how the students leveraged the tool to improve their learning and to log their sentiments while reading the material and attempting the programming activities. We find that those students who had access to the annotation tool spent an above average amount of time on the material. They also had a higher completion rate and performance compared to the control group who did not have the annotation feature available to them. Feedback from the students who used the tool was very positive. Finally, we delve deeper into analysing the annotation patterns and explore how instructors can make use of fine-grained annotation data to inform and adapt the design of CS teaching and learning materials in online or blended contexts.

CCS CONCEPTS
• Applied computing → Interactive learning environments; Distance learning; E-learning; Collaborative learning.

KEYWORDS
annotations; digital education; engagement; situated cognition

ACM Reference Format:

1 INTRODUCTION
The aim of education should be to create autonomous learners, i.e. learning to learn. Burner discusses in [2] that the purpose of education is not just to impart knowledge, but instead to facilitate thinking and problem-solving skills which can then be transferred to a range of situations. This does not obviate the classroom teacher; it will always be necessary not only to arrange the conditions of learning but also to discuss, debrief, and encourage future explorations by asking the right questions or giving an appropriate direction at the most opportune time. Rather, the environment should stimulate interest and facilitate learning.

Learning is intrinsically linked to physically situated cognition [6]. Literature confirms that since we learn best through enactive encounters, appropriate experiences with materials assist conceptual development [1]. The four central ideas in situated cognition (the 4Es) are: (1) the embodiment thesis argues that cognition encompasses both the mind and the body; (2) the embed thesis maintains that people exploit features of the physical and social environment to increase their cognitive abilities; (3) the enactive thesis describes the cognition as dependent upon a person’s interactions with the world and (4) the extended cognition thesis posits that cognition emerges from interacting with the artifacts and others.

It is well understood that environmental structure is critical to human cognition and this is evident in the physical spaces at institutions around us. It is even noticeable from the architectural perspective. For example, many universities incorporate strategies to promote social engagement, communication and collaboration by encouraging social density in so-called attractor spaces such as workrooms fitted with shared screens, courtyard gardens, games rooms, etc. Strategically planned seating configurations around campus and in libraries, and open office spaces for research students similarly serve the purpose of facilitating social knowledge construction. The challenge is to have similar embodied experience in the virtual learning spaces.

2 EMBODIED EXPERIENCE IN AND WITH ENVIRONMENT
The embodiment thesis maintains that cognition depends upon physical characteristics of the body [18]; its sensory and motor capabilities shape the mind [16]. A major historical influence for the embodiment thesis is Gibson’s work on the theory of affordances [7]. Gibson believed that people understand the world in terms of functional relevance and possibilities for action (affordances). He defines affordances as a relationship between people and environment, dependent upon the person’s intentions and physical abilities with respect to action opportunities provided by features of the environment.

This allows people to feel that tools and objects used during learning become an extension of themselves, serving to organise
their knowledge construction and understanding. Using the tools allows learners to externalise the idea and/or thought process. This, in turn, enables them to receive feedback from the environment (peers and others) in response to which they can initiate new actions.

Annotations are a tool that offers their users a means to (1) identify and process new information, (2) record interpretation and inference, (3) assist problem structuring through solution attempts and (4) reflect on the process of reading in that exact moment. Studies have shown a firm relationship between thinking and acting with tools, for example, demonstrating activation of motor processes in the brain when people think about using tools, say words associated with tool use, or watch someone else use a tool [10, 15].

Embodied and embedded cognition often go hand-in-hand and are sometimes referred to collectively as embodied, embedded cognition [3]. Where embodied cognition considers how people use their bodies to help them think, embedded cognition theory considers how people use features of their environment to improve their cognitive abilities [16]. People do not store or process information they can easily off-load to the environment, a process known as cognitive bootstrapping [4]. They exploit aspects of their environments as things to think with, helping them better understand, evaluate, and elaborate on ideas.

3 THE ANNOTATION TOOL

The social annotation platform serves as a transparent tool in the knowledge-generation process. Students act using the features of the annotation tool to identify, process and organise knowledge. Annotating, then, is a method of abstracting and compressing information which can be classified as ‘seeing with a tool’. Annotations are additionally used as a tool to off-load cognitive work to the environment (cognitive bootstrapping). Numerous studies cite annotation as a ubiquitous companion activity to responsive reading, and the ability to annotate documents is reported as an essential and often requested feature of digital reading interfaces for education [11, 13, 17, 19]. Annotations vary widely in purpose, content and desired permanence but they all share a few important common properties. Namely their creation is always interleaved with the act of reading and they are anchored, i.e. they pertain to a specific portion of the text.

In this research, we extended the Hypothesis tool [8] which allows students to asynchronously annotate learning material such as readings, lecture notes and problem sets in a chat-like fashion. We investigate two aspects of annotation use. Firstly, we explore the affordance of the tool in assisting Computing Science students’ knowledge construction process. Secondly, we analyse how annotations enable educators to obtain richer and more actionable insights from the use of learning material.

The student view of the course page is shown in Figure 1. It shows what the student sees after accessing the reading material and highlighting a specific passage on a page. Six different tagging options were made available to students to categorise their annotations. Upon selecting one of the six annotation categories, a conversation window opens in the right hand pane where the student can pose a question or post a comment. Figure 1 shows a portion of text that has been highlighted in the learning material and the six (6) annotation options being displayed below the highlight. Table 1 shows the six pre-defined annotation options that students can use when posting an annotation.

Table 1: Six different annotation categories for students

<table>
<thead>
<tr>
<th>Category</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comment</td>
<td>to contribute opinions and remarks</td>
</tr>
<tr>
<td>Question</td>
<td>to elicit information or response from peers or instructors</td>
</tr>
<tr>
<td>Errata</td>
<td>to report inaccuracies in the learning material</td>
</tr>
<tr>
<td>Important</td>
<td>to encode important concepts/terminologies</td>
</tr>
<tr>
<td>Confusing</td>
<td>to report material that need further clarification or elaboration.</td>
</tr>
<tr>
<td>Interesting</td>
<td>to identify concepts or discussion that are notable and one may want to explore in future</td>
</tr>
</tbody>
</table>

Students can also add their own custom tags to their annotation to categorise them and the corresponding text. These tags are searchable and can be used to connect with others working on the same topic or to follow a group’s annotation activity across
the material. Annotations are public by default but can be made private. If the annotation is public, other students can respond asynchronously to the conversation as shown in Figure 2. Students can upvote, share or flag annotations made by others. The search box on the top right corner of the sidebar lets students search annotations by username, tag or keyword.

Figure 2: The annotation tools shows a user responding to an annotation in the right-hand side-bar

For instructors, the annotation platform also includes an integrated dashboard (Fig. 9), which provides real-time feedback on how students are engaging with the reading task. This is further discussed in Section 5.3.

4 METHODOLOGY

4.1 Research questions

The goal of this research is to examine the affordances of the annotation tool to augment the CS learning space and investigate how it enhances learning. We answer the following specific questions:

1. How do students perceive and use annotations whilst engaging with learning materials?
2. How does the social annotation platform augment student participation and performance?
3. What useful insights does the annotation tool generate about the students learning and how can these insights be used by instructors to enhance teaching?

4.2 Participants and settings

Two workshops were advertised on “Data Visualisation using Python” during the semester break targeting undergraduate and post-graduate students of Engineering and Information Technology at Monash university. A total of 57 students enrolled in the workshops. Each workshop was divided into two phases:

1. Preparatory Phase: Students were given preparatory material, i.e. a 20-page study guide comprising of readings, coding instructions and quizzes (multiple-choice and programming exercises) on data visualisation using Python. Students had to complete this task online on their own, at home, prior to the face-to-face session. The material was made available via a content delivery platform as a HTML e-book. Students could use the annotation feature on the platform to annotate the pages in their own time. All reading interactions on the platform were recorded. The choice to annotate was completely voluntary and no marks were awarded for making annotations. However, students were informed that the annotations made would be used to adapt the teaching focus (content and exercises) of the half-day face-to-face workshop session. Students could see how others were annotating and could respond to each others annotations on the learning material.

2. Face-to-Face Session: A 3-hour face-to-face session was delivered to the students a week after the preparatory phase was concluded. For these, the teaching material was adapted in response to the students’ experience with the learning material as captured in the annotations.

The experimental group consisted of 37 participants. These had access to the annotation feature enabled within their platform. The control group comprised of 20 students who did not have access to the annotation tool. The shared demographics of both groups is in Figure 3. Apart from the ability to use annotations, preparatory course material, quizzes and schedule for both groups were completely identical.

Figure 3: Characteristics of the Participants

The scenario typifies a traditional Computer Science course where students are expected to complete their reading and preparatory work at home and the actual problem-solving or coding exercises take place during the face-to-face session in the presence of an instructor. Figure 3 summarizes the characteristics of the participants who enrolled in the workshop.

4.3 Procedure

To evaluate the efficacy of the annotation tool, we performed the analysis as described below. Fine-grained data regarding annotations, the nature or category, annotation position within the document, author, posting timestamp, counts and any reply/upvote were identified as independent variables. The dependent variable in the experiment was the completion rate and quiz score. We first extracted the above-mentioned independent annotation metrics that could describe the students’ annotation behaviour. We aggregated some of these data as a way of describing how much and when, relative to class, students were participating. We used the statistical software SPSS to calculate correlations between specific annotation
metrics and time spent, completion rate and student performance. Finally, we report more qualitative insights into how the instructor used annotation information to adapt the teaching approaches in the classroom and the student experience of using the annotation tool.

5 RESULTS

5.1 Students use of the annotation tool

During the preparatory week 307 annotations were made by the 36 students in the twenty (20) page document. Thirty-six (36) out of thirty-seven (37) students contributed annotations during this phase.

![Figure 4: Distribution of the number of annotations made](image)

**Figure 4:** Distribution of the number of annotations made.

Figure 4 shows the frequency of students that made particular numbers of annotations. The average number of annotations per page was 15.3 ($SD = 2.2$) and the average number of annotation per student was 8.57 ($SD = 2.4$). The average number of interactions with an annotation (clicks/views/upvote) across the whole document was 24.6 ($SD = 4.3$). We believe this value was low because annotating was entirely voluntary. We hope to investigate the impact of incentives in future experiments.

![Figure 5: Proportion of annotations made by category.](image)

**Figure 5:** Proportion of annotations made by category.

Figure 5 shows the distribution of annotations by the six different annotation categories. Most of the annotations made were comments (summarisation and elaborations)—used to stimulate thinking and important tags—used to indicate key concepts (cognitive bootstrapping). These are reported as common strategies used by students to understand/summarise notes and help retention of knowledge [16] and confirmed by our student survey results in Figure 10.

5.2 Annotating increases participation and performance

We see in Figure 6 that the time spent reading online material is significantly higher for the cohort that used the annotation tool. The minimum preparation time for the workshop was recommended to be at least 4 hours. Approximately 73% of the students who used the annotation platform spent well above the suggested time (> 4 hours) compared to only 35% of students from the control group.

![Figure 6: Reading time of experimental vs control group.](image)

**Figure 6:** Reading time of experimental vs control group.

![Figure 7: Completion rate of experimental vs control group.](image)

**Figure 7:** Completion rate of experimental vs control group.

Figure 7 shows the extent to which students completed their preparatory material from the two cohorts. Close to 57% of the students who were using annotations completed all the readings during the preparatory two weeks compared to only 36% completion rate obtained from the control group.

![Figure 8: Performance of experimental vs control group.](image)

**Figure 8:** Performance of experimental vs control group.

Some literature reports that students only read on average 28% of the assigned pre-readings [5]. However, this was a report on psychology courses and we could not find any figures for CS courses (although anecdotal from experience, it is similarly low). At 57%, our result is considerably higher than what is reported in the literature and the observed completion rate of the control group.
Figure 8 above shows that students using the annotation tool seem generally to have done marginally better in the module quizzes. This is more pronounced for the later (more advanced quizzes). The average score for quizzes 2-4 for the cohort that used the annotation was 8 – 10% higher when compared to the cohort where annotation tool was not being used ($p < 0.05$).

5.3 Obtaining actionable insights from annotation data

One of the benefits we foresee from using annotation as a data source is that it provides contextual and qualitative feedback to instructors for actioning interventions—something that is much needed in programming courses to understand students’ difficulties with content and concepts.

The integrated dashboard (Fig. 9) provides instructors with near real-time feedback on how students are engaging with specific sections of the module. The colour of the bubble corresponds to the category of annotation it belongs to and the size of the bubble corresponds to the frequency of annotations made on that module. Clicking on the bubble leads the instructor to an itemized list of all annotations that were made on that page corresponding to the respective annotation classification.

The philosophy behind the annotation breakdown report is based on Just-in-Time-Teaching [12], which uses instant feedback from students to inform teachers on where students are routinely grappling with difficult concepts. Their reactions to the learning materials (aggregated according to the six different tagging options and learning modules) can be extremely valuable in communicating student experience in near real-time. We discuss two scenarios where this leads to useful insights for the instructor.

5.3.1 Using Annotation Data to Improve Teaching Material.

Nine out of ten (9/10) annotations posted in Module 4.6 were tagged as confusing (Fig. 9). The annotation listing against the section showed that the module focused on creating "Small Multiple" plots using Python. This insight led the instructor to make the following improvements to the teaching material:

1. The instructor created a guided tutorial on "Small Multiples" as a pre-workshop exercise for the students.
2. Two additional slides on "Small Multiple" were included in the face-to-face material to be discussed during the lecture.

Although the entire class had access to this supplementary material, the interventions were to help mainly the students who reported confusion through their annotation posting. These students usually are the "at-risk" cases (non-completers or low performers) as reported by our analysis in the previous section. The survey at the end of the workshop showed positive feedback on the quick remediation action taken of the instructor. A few of the responses we got from the students included:

"This is an excellent tutorial. It clarifies all my doubts. Thank you for providing this."

"Just what I was looking for."

"Thanks. Here is another link I found useful: https://python-graphgallery.com/125-small-multiples-for-line-chart/"

5.3.2 Using annotation data to adapt face-to-face teaching.

Another benefit worth reporting is the value of annotation data for adapting the face-to-face teaching approach in the classroom. The insights received from the annotation breakdown report (Fig. 9) was valuable for the instructor to tailor their teaching strategy and time allocation for topics in the face-to-face session. Topics which had recorded a high number of confusion annotations were emphasized more during the lecture. Additionally, during the workshop session itself, students were annotating on the lecture slides and programming exercises. The instructor was able to get a real-time view of student difficulty as students progressed during the workshop. Some students preferred asking questions in writing or flagging concepts in the teaching material rather than asking orally. After examining the list of annotations, the instructor was able to revisit some of the highly annotated concepts again during the workshop.

5.4 Student Experiences with the Annotation Platform

We surveyed the students at the conclusion of the workshop to understand their experiences with the social annotation platform. Figure 10 shows that 42% of the students actively utilised the annotation platform ("Very Often" and "Always") and for most of
the anticipated activities—but most commonly for note taking and reporting issues (confusion or errors) with material.

In linking the annotation categories to these steps, we hoped that they would to some degree be indicative of these steps: (1) Interesting—engaging with inspiring material, (2) Important—encoding key concepts, (3) Comment—reflecting deeper thinking and elaboration and (4) Confusion/Help—critical self-evaluation.

61% of the students in the experimental group had not used an online annotation tool before. We sought the group’s feedback after this experiment on the effectiveness of annotations as opposed to discussion forums as a tool for learning. Figure 12 highlights that 79% of the student rated the annotation tool highly towards supporting their knowledge construction (giving Level 4 and Level 5 ratings) compared to 54% of students who regarded the discussion forum at that same level. The Level 5 rating may have been rare as we encountered a small technical glitch in the annotation platform during the preparatory week. Even though this was fixed quickly it may have impacted on the user experience and ratings.

Figure 10: Student response on how often they used the annotation tool and the reason for using it

Figure 11: Students rating of usefulness of features

The annotation categories used in the tool were chosen to reflect the steps in the learning and teaching strategy framework discussed in [14]. According to this framework, effective teaching materials should be designed to address four key incremental steps in the learning process: (1) engaging interest, (2) encoding important information, (3) elaborating meaning, and (4) evaluating progress. In linking the annotation categories to these steps, we hoped that they would to some degree be indicative of these steps: (1) Interesting—engaging with inspiring material, (2) Important—encoding key concepts, (3) Comment—reflecting deeper thinking and elaboration and (4) Confusion/Help—critical self-evaluation.

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Figure 12: Students preference of Annotation Tool vs Discussion Forum

6 CONCLUSION

This study explored the efficacy of an annotation platform as a tool to empower learners in the knowledge construction process. We found that completion rate and time spent on learning was higher for students that used the annotation platform. Additionally, the performance of these students was generally higher as well.

We have also shown how an annotation platform can be a way to extend a learning environment. It can be considered as a transparent mechanism to facilitate the identification, processing and organization of knowledge and as a tool for cognitive bootstrapping. We found that the students rated the annotation tool as highly valuable compared to the traditional alternative of a discussion forum.

Annotations give students the opportunity to comment on the learning materials provided. Thus, they can not only be seen as an indicator of whether students are struggling but also as "... an assessment of how well the instructor was doing as an explainer" [20]. The dashboard in Figure 9 can be used for this dual purpose. Annotation analysis thus provides valuable contextual feedback on student experience to guide content creators in improving the teaching materials.

Our next step is to run large-scale versions of our experiment in real-life university courses with enrolments in excess of 600 students for a whole semester. Fine-grained document usage and annotation data will be collected to closely examine the capabilities, uses, and limitations of this data source. In contrast to the present study, which analysed annotation use in isolation, we will perform a joint analysis of annotation use and other document usage data to analyse how these data sources can complement each other. We are specifically looking at complementing annotation use data with document traversal paths and reading time information in the hope that a joint analysis afford us insights that we cannot obtain from either data source in isolation.

User studies for students and instructors, comprising of think-aloud sessions, surveys and interviews, will be undertaken to further understand how students perceive and use annotations in real-life courses and to evaluate the usefulness of the analytics. Based on our study, we also see real potential for annotation tools beyond conventional instruction materials, namely in peer-based learning environments for collaborative coding, such as Google Colab.

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REFERENCES


